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Issued: 2014-03-11

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# Responsive Space

## Program Brief

Eric E. Dors

November 2012

# Los Alamos National Laboratory:
## A national security science laboratory serving the national interest

- We anticipate, innovate, and deliver solutions
- We span the spectrum from Discovery through Applied Science to Prototypes
- We use the outstanding science, engineering, and technology from our core stockpile stewardship mission for other national needs

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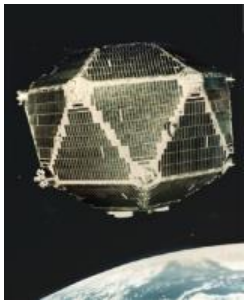
# Global Security Organization

| July 2012 GS Strategic Plan | |
|---|---|
| **Mission** | Protect against emerging, proliferant, and unconventional nuclear threats – regardless of origin |
| **Vision** | To globally reduce threats to the security of the United States and our allies |
| **Goal** | Make significant, integrated science and technology contributions to the end-to-end missions of the U.S. Government that protect against global emerging and nuclear threats, from the earliest adversary planning through resilient event response |

# LANL has a long history of success in space!

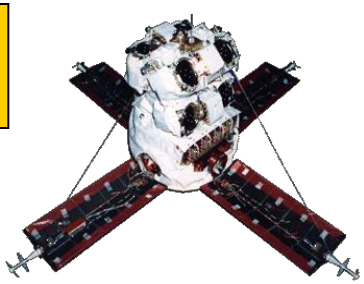
## Many of these programs have been fruitful collaborations with you!



VELA

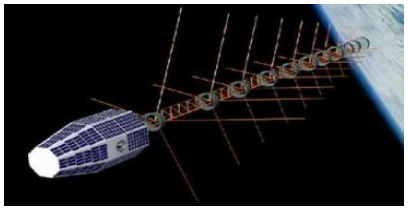
Science => Mission Design => Instrumentation => Testing => Launch => Operations => Analysis

**50+ years of experience**



ALEXIS

DSP

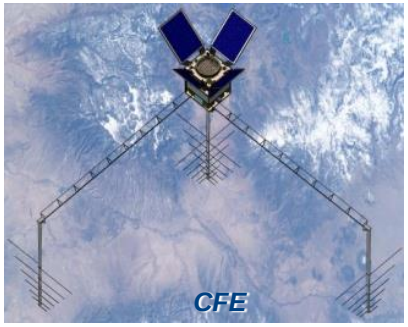


FORTE

MTI

**~1400 sensors**
**on**
**~400 instruments**
**on**
**~60 satellites**

GPS



CFE

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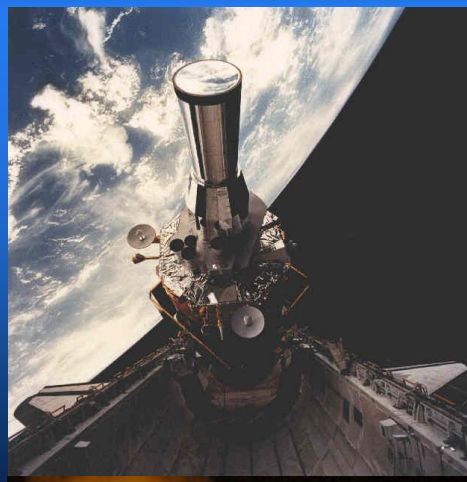
# Many of our most important national missions are performed or enabled by space capabilities.

- Geospatial intelligence
- Communications (tactical and strategic)
- Weather forecasting; Future: Climate / Carbon Treaty
- Intelligence, Surveillance, and Reconnaissance
- Missile Warning
- Position, Navigation, and Timing
- Space situational awareness / space protection
- Nuclear explosion monitoring
- …



These missions support many parts of the US Government in treaty verification, war fighting, and intelligence applications

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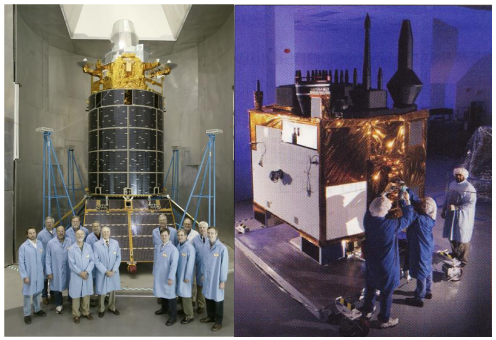
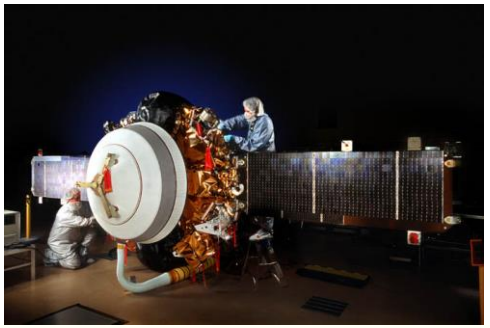
# Los Alamos has a history of successful contribution to many space missions across all architectural elements

New missions are enabled, existing missions are supported more efficiently (SSA)



National security missions develop capability relevant to basic research (SNDD)

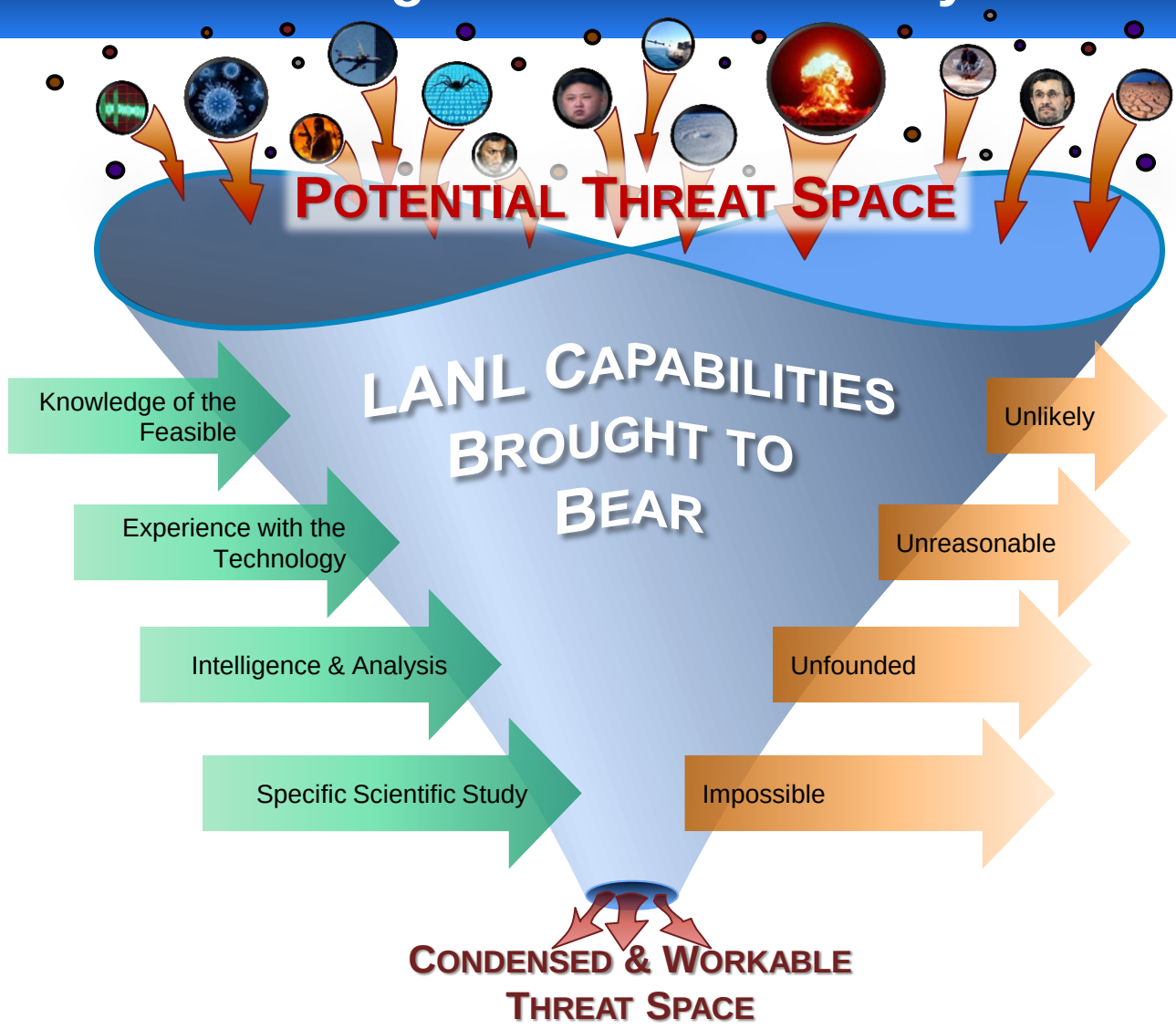
Basic research promotes the development of revolutionary new techniques and capabilities (Space environment modeling)



- Capabilities from across the laboratory have been key to successful execution
- LANL's science-based approach to national security brings unique strengths
- We seek leverage broad capabilities laboratory for strategic thrusts in SPACE

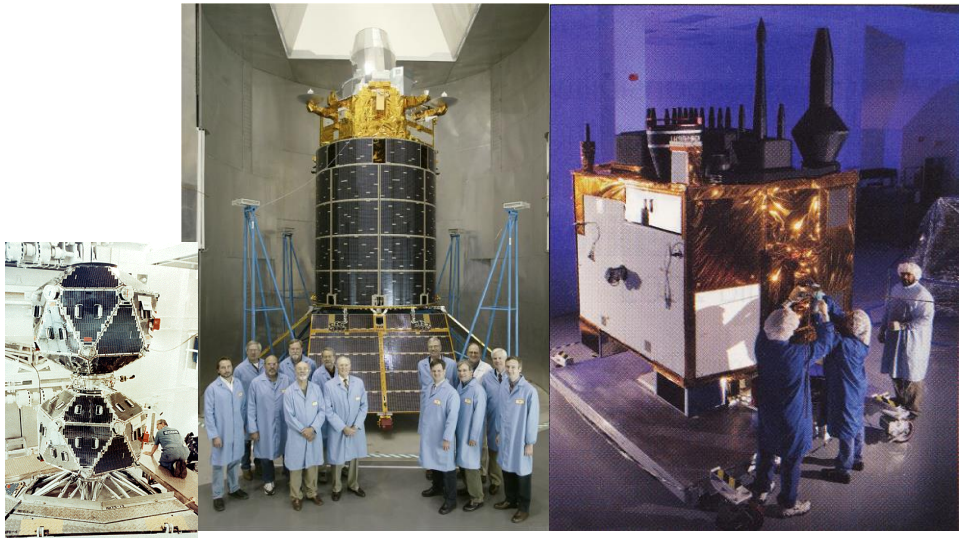
# Emerging Threats – Narrowing Down From Infinity

- **Infinite potential threats**
- **Utilize combined expertise and scientific understanding of threat space, intelligence, & cutting edge technology to narrow in on the feasible and higher potential threats**
- **Devise solutions to most concerning threats**

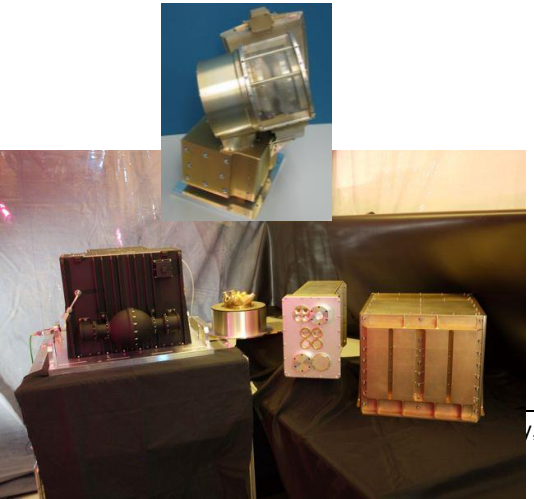


# Five decades of satellite instrumentation heritage provides an intellectual foundation for innovative new solutions.

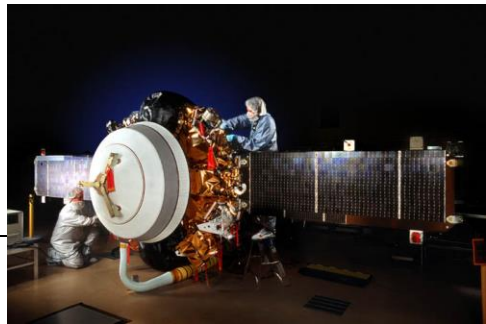
New missions are enabled, existing missions are supported more efficiently (SSA)



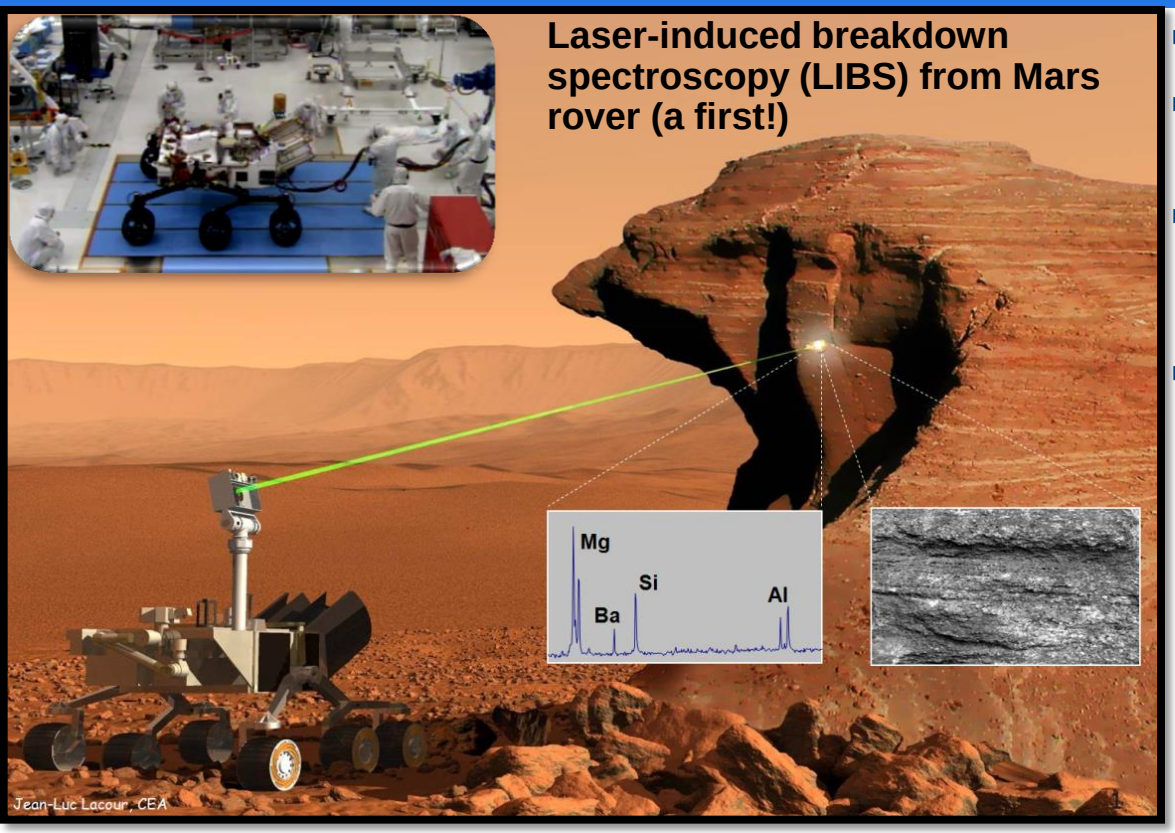
National security missions develop capability relevant to basic research (SNDD)



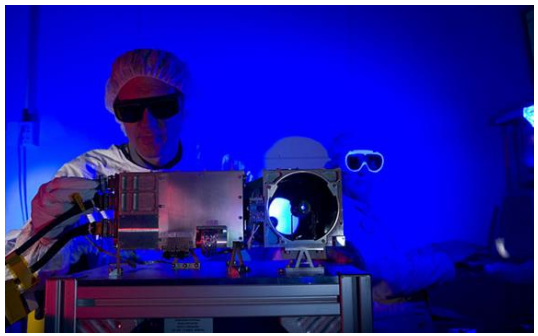
Basic research promotes the development of revolutionary new techniques and capabilities (Space environment modeling)



# NSRD Space Science Accomplishments: ChemCam
## Determining the Past and Present Habitability of Mars




- **Mars Science Laboratory: $2.5B**
- **ChemCam, joint project with French Space Agency, led by LANL: $40M**
- **LIBS technique developed jointly by LANL Planetary and Proliferation Detection programs**
- **Joint investments benefit both exploration and national security programs (NA-24)**



1998: First NASA concept funding to LANL

2003: LANL wins R&D 100 award

2004: ChemCam selected for Curiosity Rover

2011 Nov 26: Launch

2012 Aug 5 Landing

2014: End of Mission



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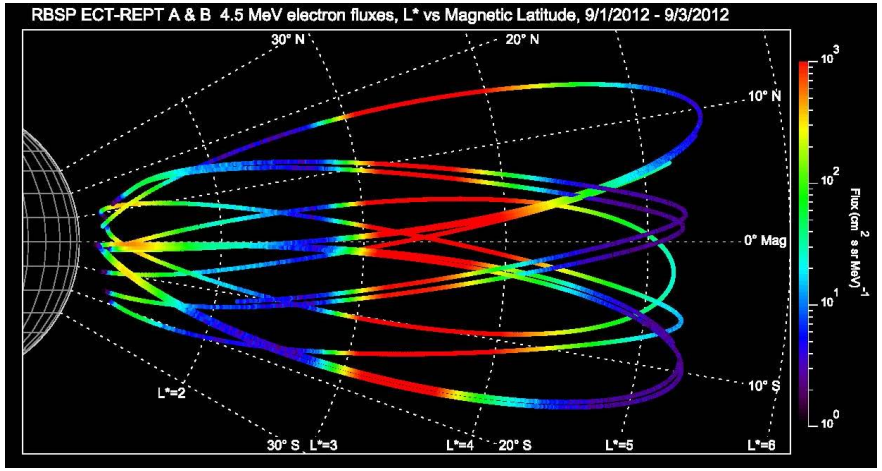
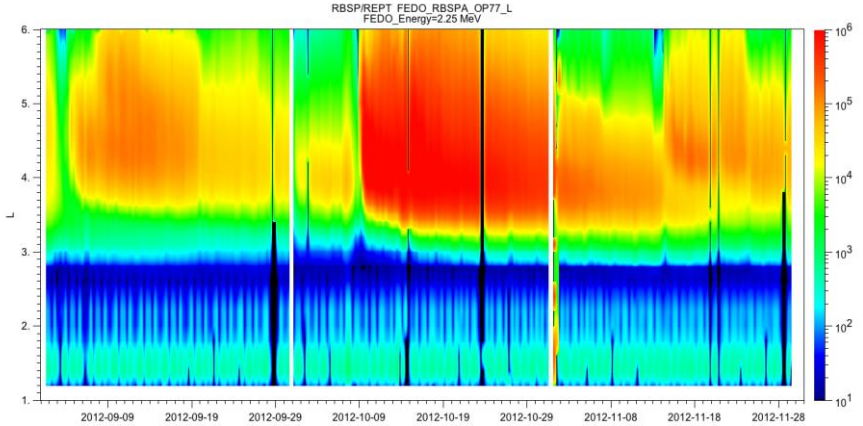
http://www.msl-chemcam.com/

# Space Science Accomplishments: Launch of Radiation Belt Storm Probes

**Description: Launch August 30, 2012. Normal Science Operations October 1, 2012. First results submitted to Science.**

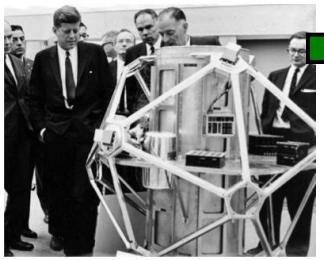


# Los Alamos, Sandia, and the USAF have teamed to provide global persistent monitoring of nuclear explosions since 1963. Capabilities are continuously evolved to meet the evolving threats.

## Vela

**Vela Hotel**
*Optical*
*X-ray*
*EMP*
*Particle*
*Neutron*
*Gamma*



1963-1985
6 pairs

## Defense Support Program (DSP)

**Advanced Radiation Detection Capability**
*X-ray*
*Particle*
*Neutron*
*Gamma*
*Optical*

## Global Positioning System

**CXD**
*X-ray*
*Particle*

**BDV**
*EMP*

**BDY**
*Optical*

## Hosts of opportunity

**SABRS**
*Neutron*
*Gamma*
*Particle*
*(Optical)*

# Responsive Space Focus Area Strategy

**National Space Policy, 2010**
*- assure the use of space for all responsible parties*

**Future success is about knowledge:**
*Knowing things your adversary doesn't know, knowing them sooner, and having the capability to act.*

**National Security Space Strategy, 2011** - *space is increasingly **congested, contested and competitive** … future systems must fight through degraded environments and defeat attacks …*

## LANL is:

***Leveraging SNDD and Space Science Technology***

***Integrating Laboratory Capabilities***

- **Space Hardware and Remote Sensing**
- **Heterogeneous HPC**
- **Information Science**

***Develop Strategic Partnerships***

## Addressing Critical Missions

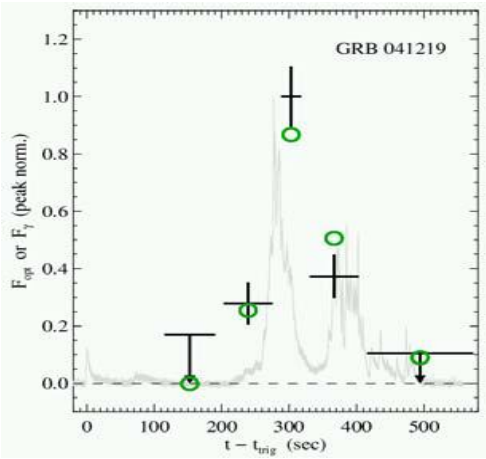
- Situational Awareness
- Space Protection
- Other

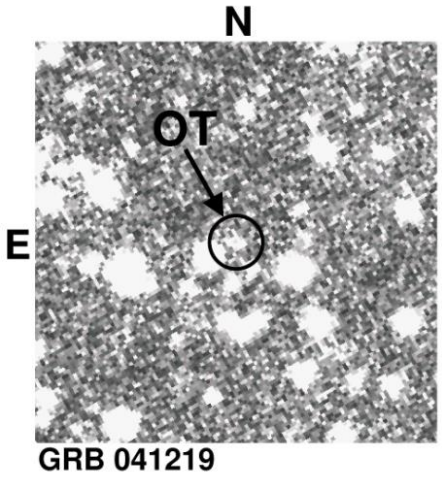
# Thinking Telescopes

## World's First "Thinking" Telescopes Network
## Coordinated Persistent Monitoring and Real-Time Follow-up

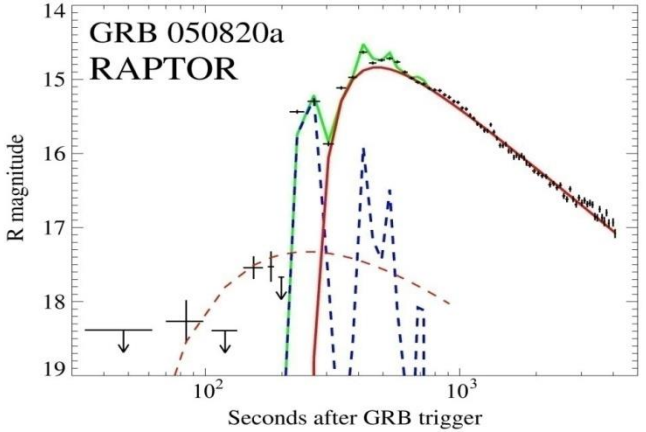
# Science Highlights

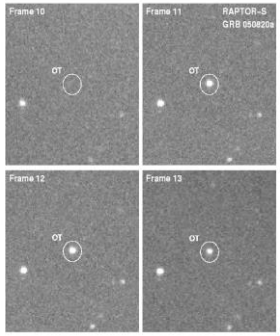
- **Discovery of prompt optical emission from Gamma-Ray Bursts**
- **Published in Nature**



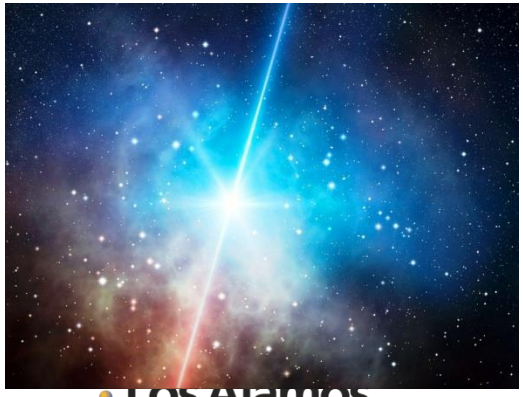



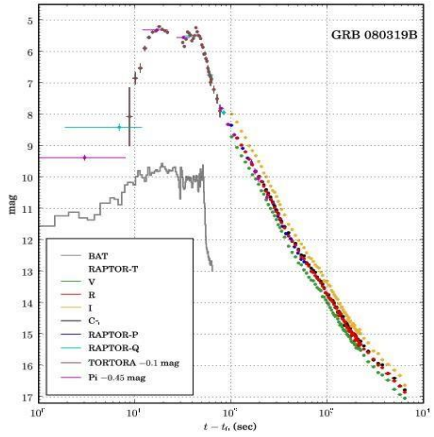

- **Taxonomy of early optical emission from GRBs**
- **A new tool for exploring the early universe**
- **Published in Nature**



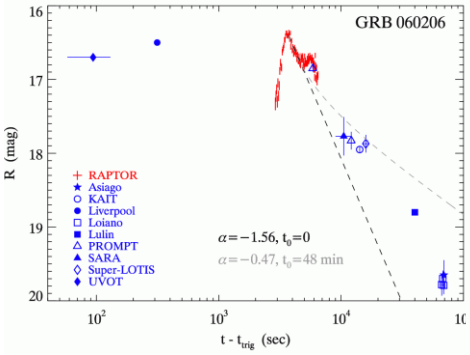



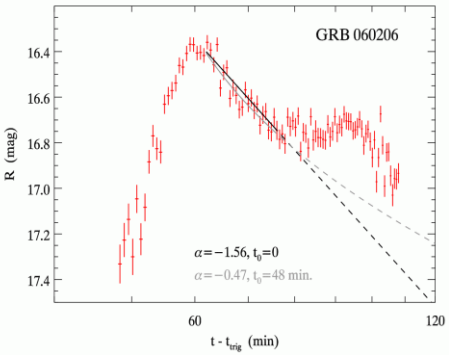

- **The Naked-Eye Gamma Ray Burst**
- **The most luminous optical object ever recorded by humankind.**
- **First simultaneous multi-color observations of early afterglow**
- **Published in Astrophysical Journal**





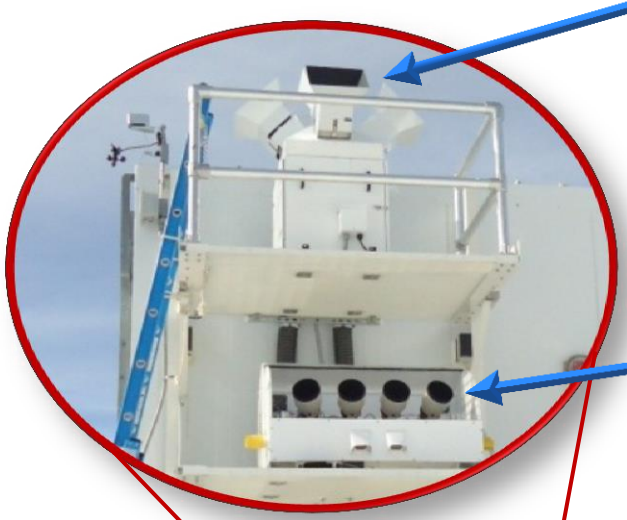

- **Autonomous optical transient detection**
- **Proof of optical flashes without Gamma-Ray component**
- **Published in Astrophysical Journal**

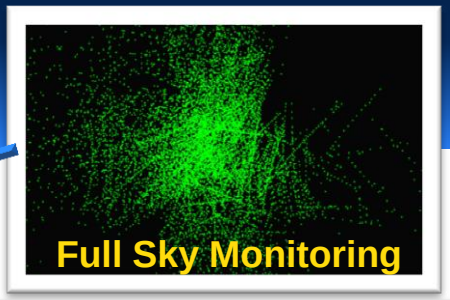


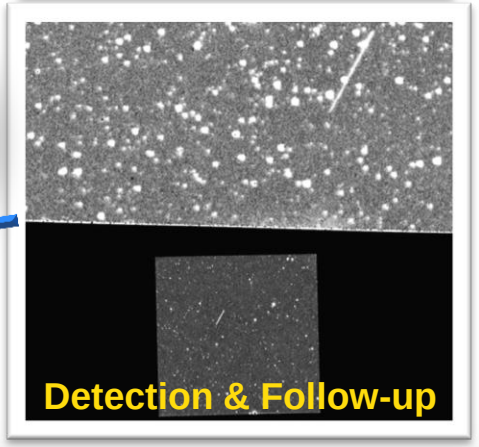



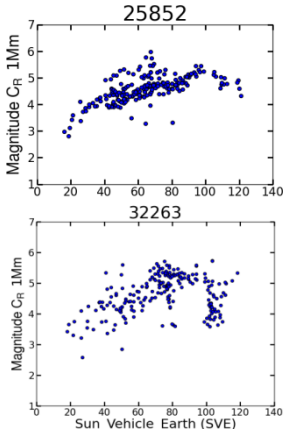
# Thinking Telescopes
## Commercial Optics for LEO Debris: COLD

- **Persistent LEO surveillance by an ecosystem of self-tasking assets**
- **Cost effective approach to persistent space situational awareness through exploitation of COTS hardware**
- **Automated object identification, follow-up and characterization enables efficient utilization of available assets**

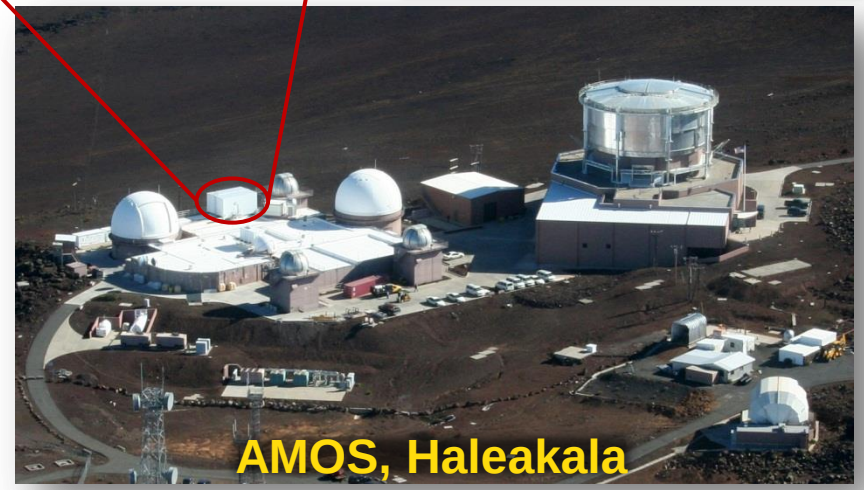





**Photometric Characterization**

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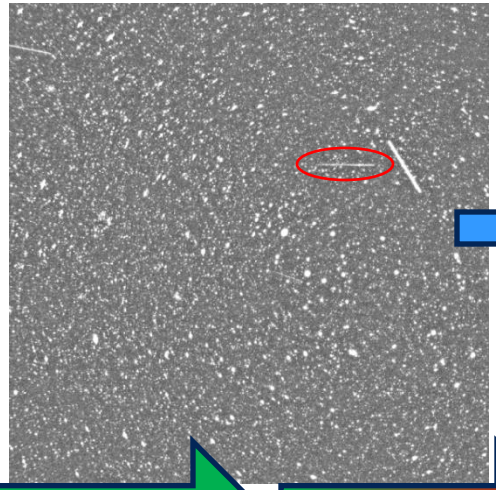
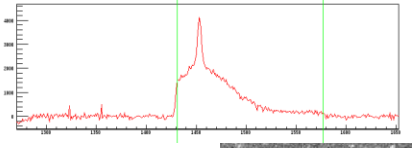
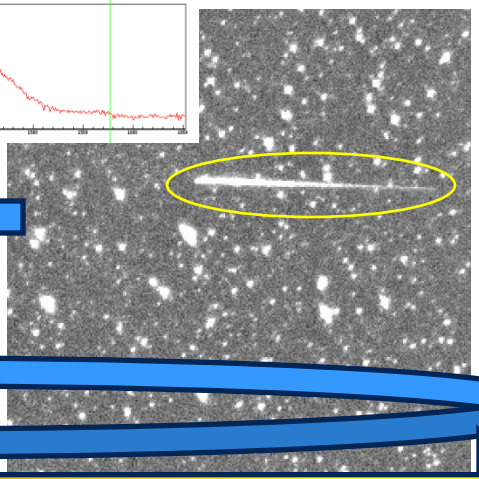
# SSA Highlight

## Automated SSA Discovery and Response







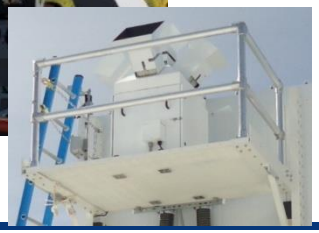
Context Database & Machine Learning

Persistent Monitoring

Anomaly Detection

Follow Up

Interrogation



T0 T+31s T+53s T+75s

Monitor | Analyze | Slew | Follow Up | Analyze | Slew | Follow Up | Analyze

Timeline

# Future Vision
## Connecting the Dots for National Security Space

***Future success is about knowledge:*** *knowing things your adversary doesn't know, knowing them sooner, and having the capability to act.*

***The Challenge:*** *How to manage an explosion of data from heterogeneous sources to support timely decisions and actions.*

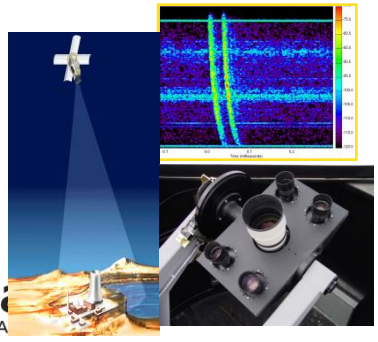
### Knowledge of Threats & Vulnerabilities
- Reversible
- Non-Reversible
- Targeted
- Systemic
- Evolving adversaries

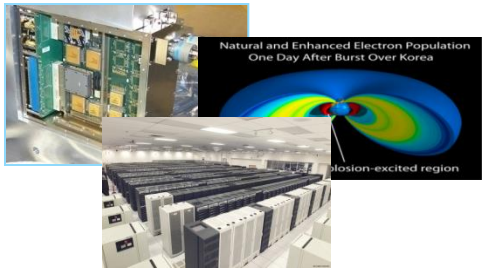
### Smart Sensors & Sensor Systems to Provide Data
- Multi-Int
- Persistent
- Thinking
- Learning
- Multi-Spectral
- New Phenomena
- Protected
- Affordable
- Interactive

### Heterogeneous Computing and Algorithms
- HPC across scales
- Huge dimensional space
- Optimum data transfers
- Noisy data
- Embedded
- Reconfigurable
- Secure
- Timely computations
- Reasonable power

### Information Science & Technology to Generate Knowledge
- Provide understanding
- All Source
- Largely automated
- Thinking
- Learning
- Timely
- Supports Tasking
- Drives recovery or reconfiguration

### Ability to Act
- Automated responses
- Informed actions
- Recover from failures & attacks
- Capabilities on board





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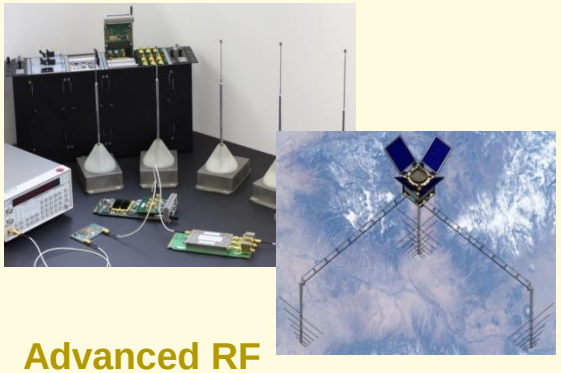
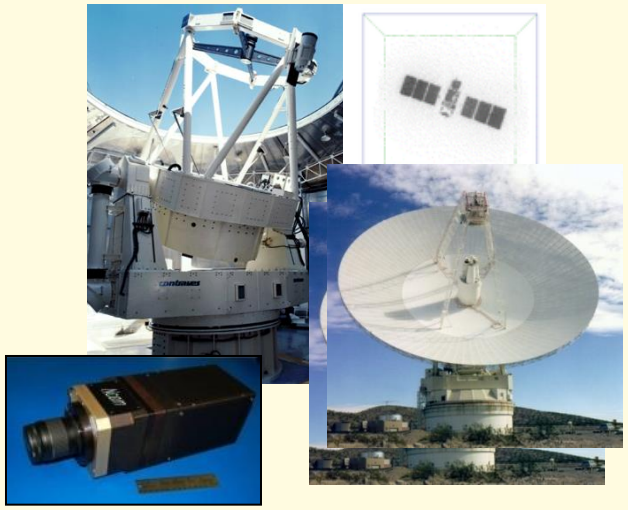
# Smart Sensors (Space, Air, and Ground)

## Characteristics

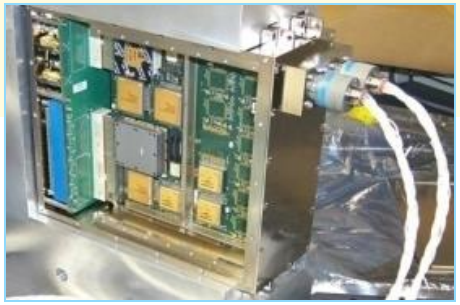
- Multi-Int
- Persistent
- Thinking
- Learning
- Multi-Spectral
- New Phenomena
- Protected
- Affordable
- Interactive



Advanced RF



Low Light and RT Technology



On-Board Processing

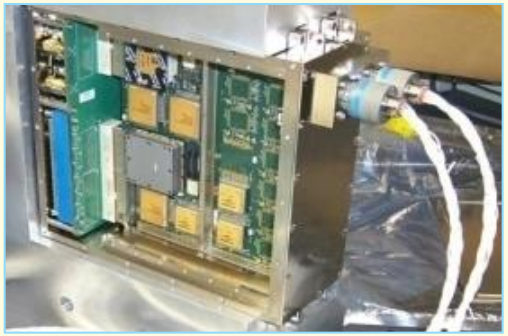
Thinking Telescopes

Multi- and Hyper-Spectral Systems

# Heterogeneous Computing and Algorithms

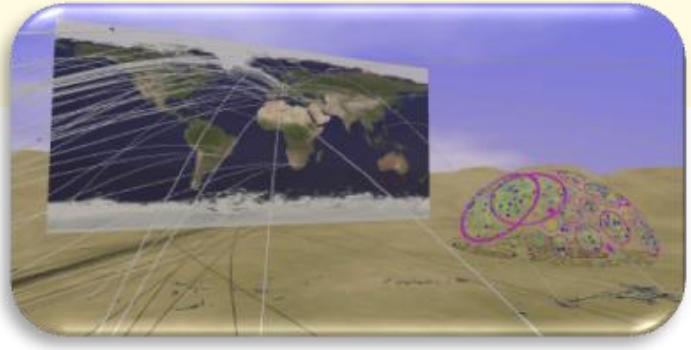
## Characteristics

- HPC across scales
- Huge dimensional space
- Optimum data transfers
- Noisy data
- Embedded
- Reconfigurable
- Secure
- Timely
- Reasonable power

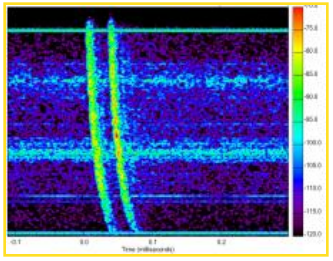


Tera-Ops On-Board

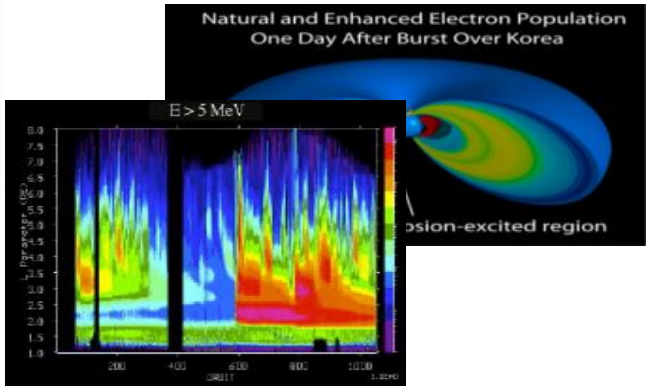
PetaFlops on the Groud



Cyber Hard Networks



Signal Processing




Complex Models

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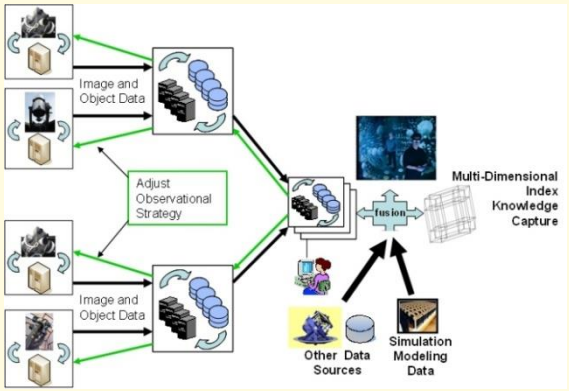
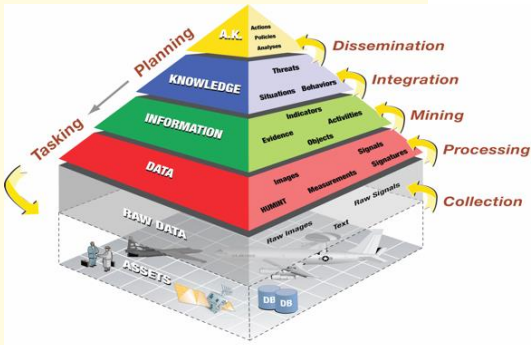
# Information Science and Knowledge Generation

## Characteristics

- Provide understanding
- All Source
- Largely automated
- Thinking
- Learning
- Timely
- Supports Tasking
- Drives recovery or reconfiguration




Scalable Distributed Data Intensive Computing

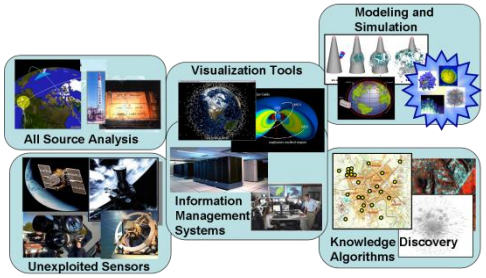



Data to Knowledge

PowerWall Theatre

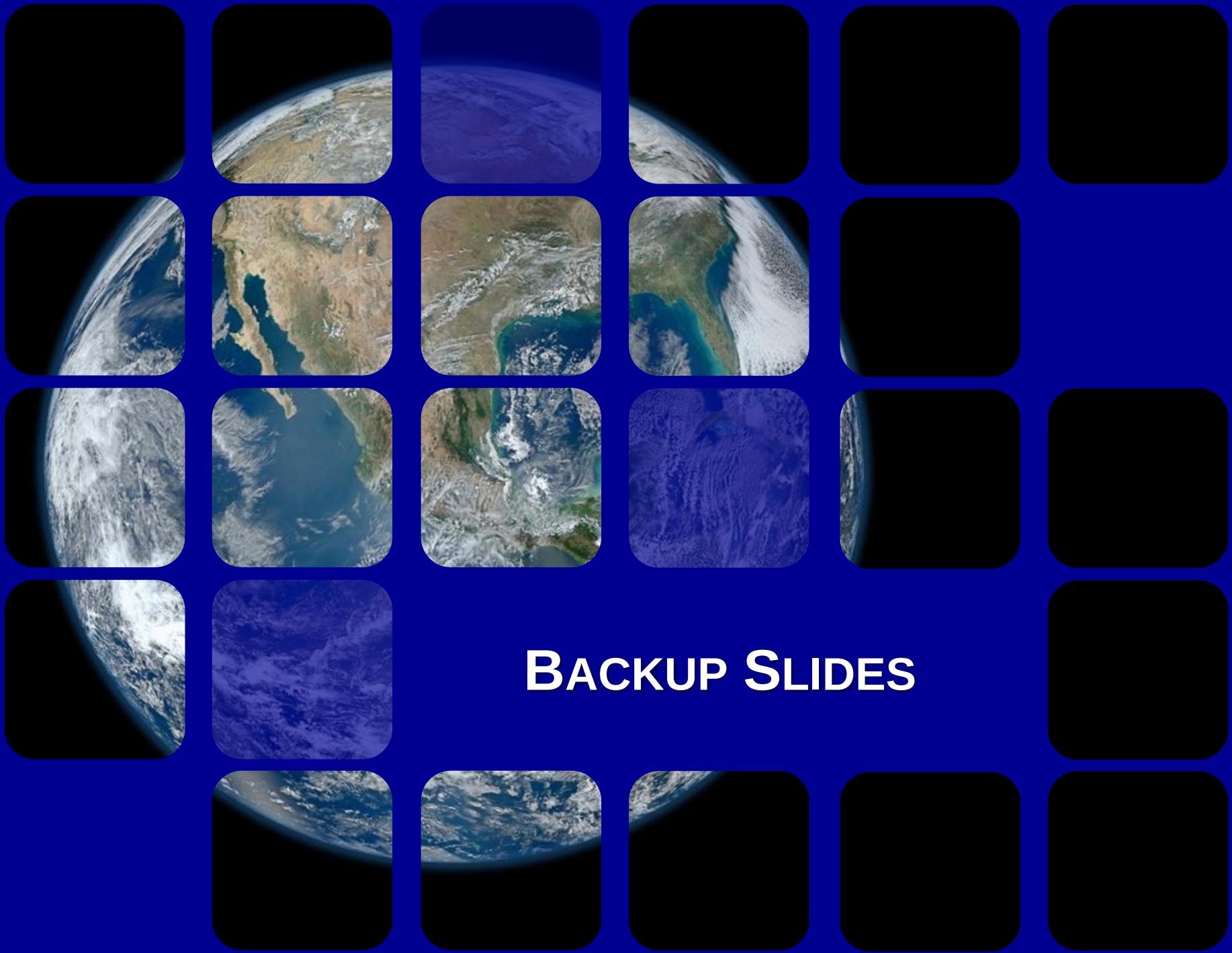
Cave 43M pixels

Advanced and Immersive Three-Dimensional Visualization




Science-Based Predictive Understanding

Actionable Knowledge

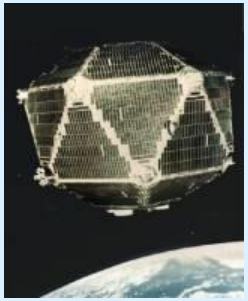


# Backup Slides

# Elements of KARNAC

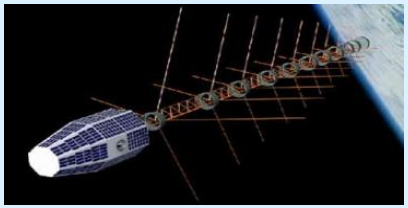
- Strategic - Vision and SSA Program Development
  - Art of the Possible
  - Build Advocacy for NNSA Lab Participation
  - Demonstrate Significant and Timely Scenarios which Illustrate NNSA Lab Capabilities
- Tactical - Deliver Lab Capability to the JSpOC
  - Provide and Deliver Solutions to Immediate Needs
  - Pathfinder to Define Transition to Operations of Net-centric Capabilities
  - Integrate with JMS CP0
- Foundational – Successfully establish Future Opportunities

# LANL has a 60-year history of successful innovation in space

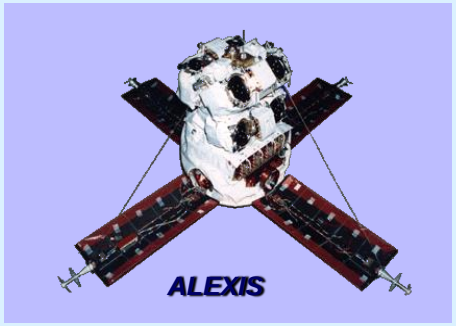


VELA

DSP

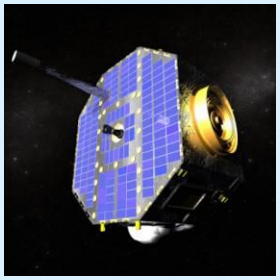


FORTE



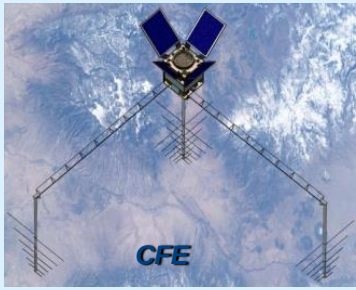
MTI

GPS



IBEX

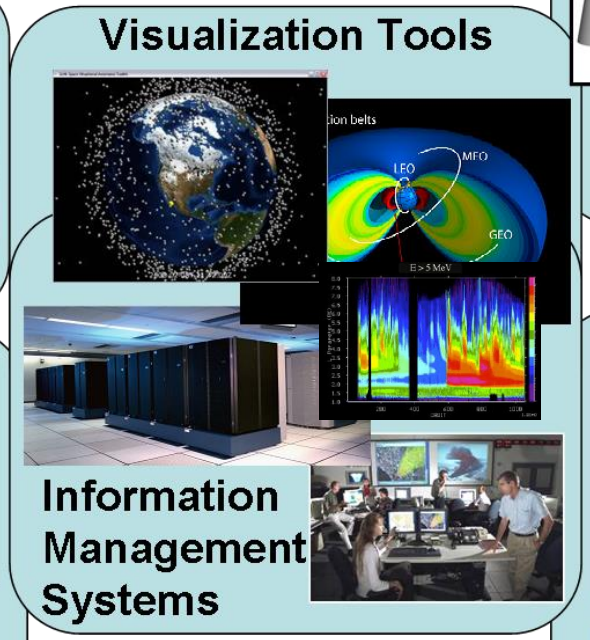
SWIFT

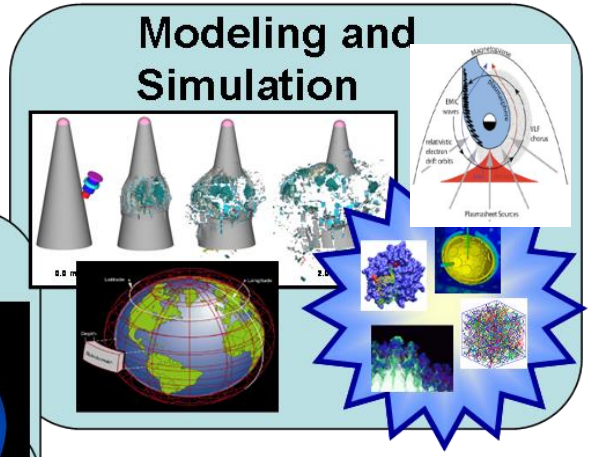


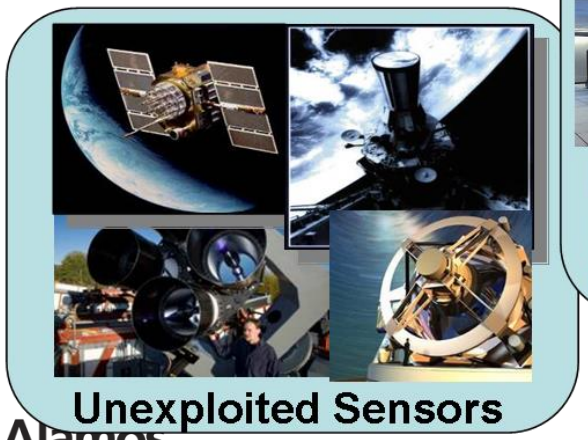

*Science => Mission Design => Instrumentation => Testing => Launch => Operations => Analysis*

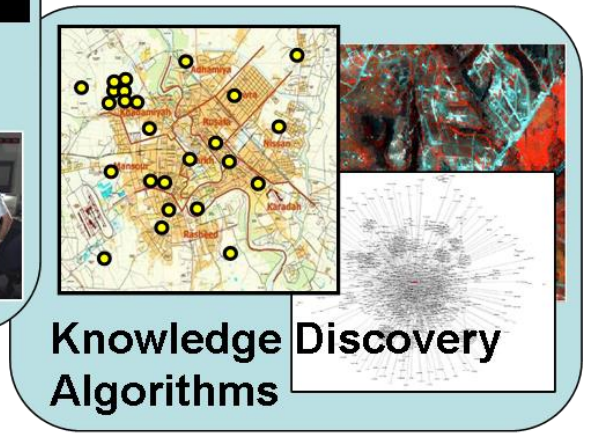
# KARNAC – Tri-Lab Partnership (LANL, LLNL, & SNL) to accelerate delivery of Actionable SSA information via novel methods

- Congressionally & DOD supported leap forward
- Multiple sensor systems
- Integrative analysis by Subject Matter Experts
- Large computational facilities
- Simulation, modeling and visualization tools



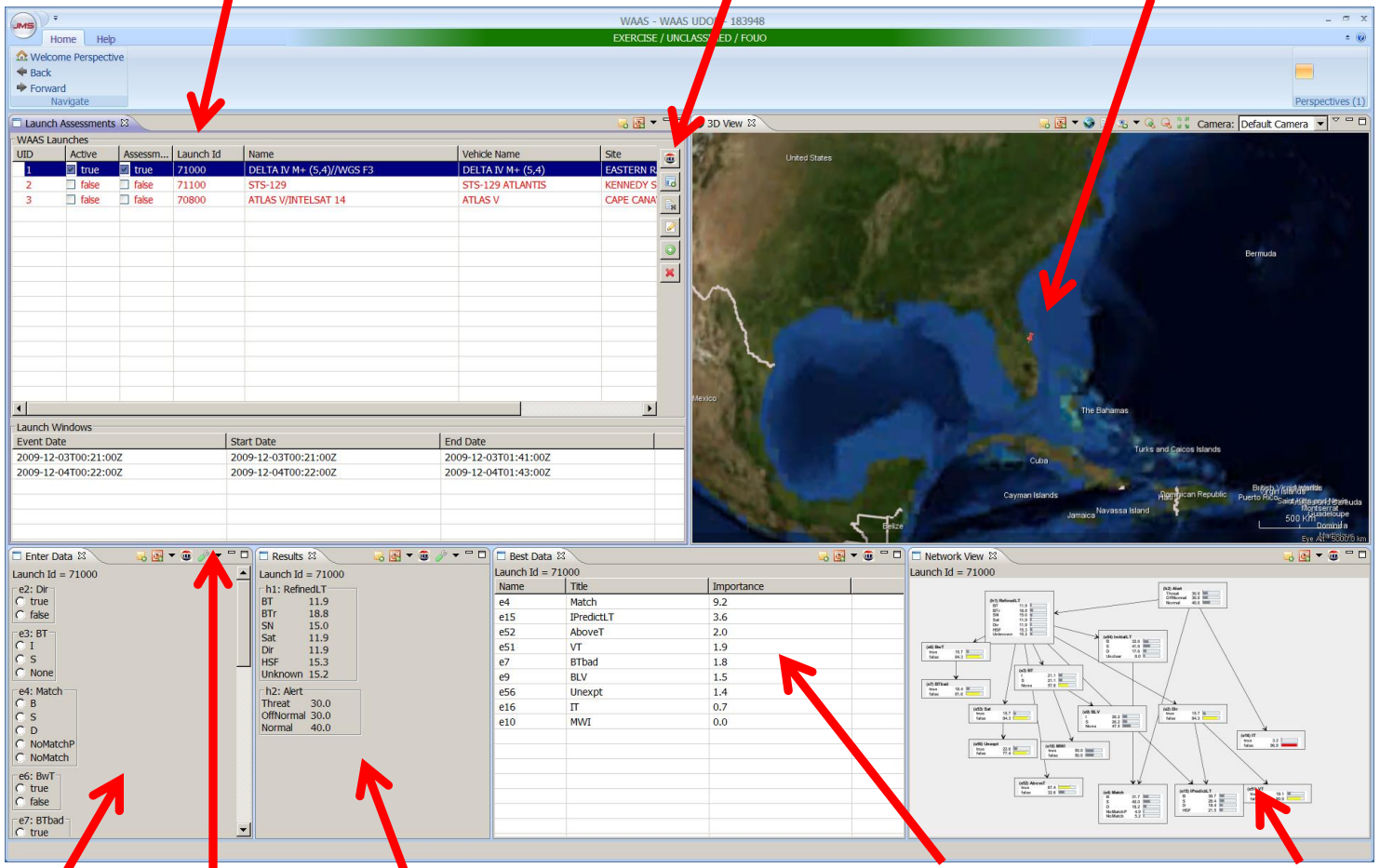



# WAAS UDOP Perspective (Pause)

Launch List & Active Assessments List Mgt Tools

Visualize launch sites and threatened sats on WorldWind




Enter Evidence

Probabilities (%) for each outcome resulting from the evidence

Best evidence to get next

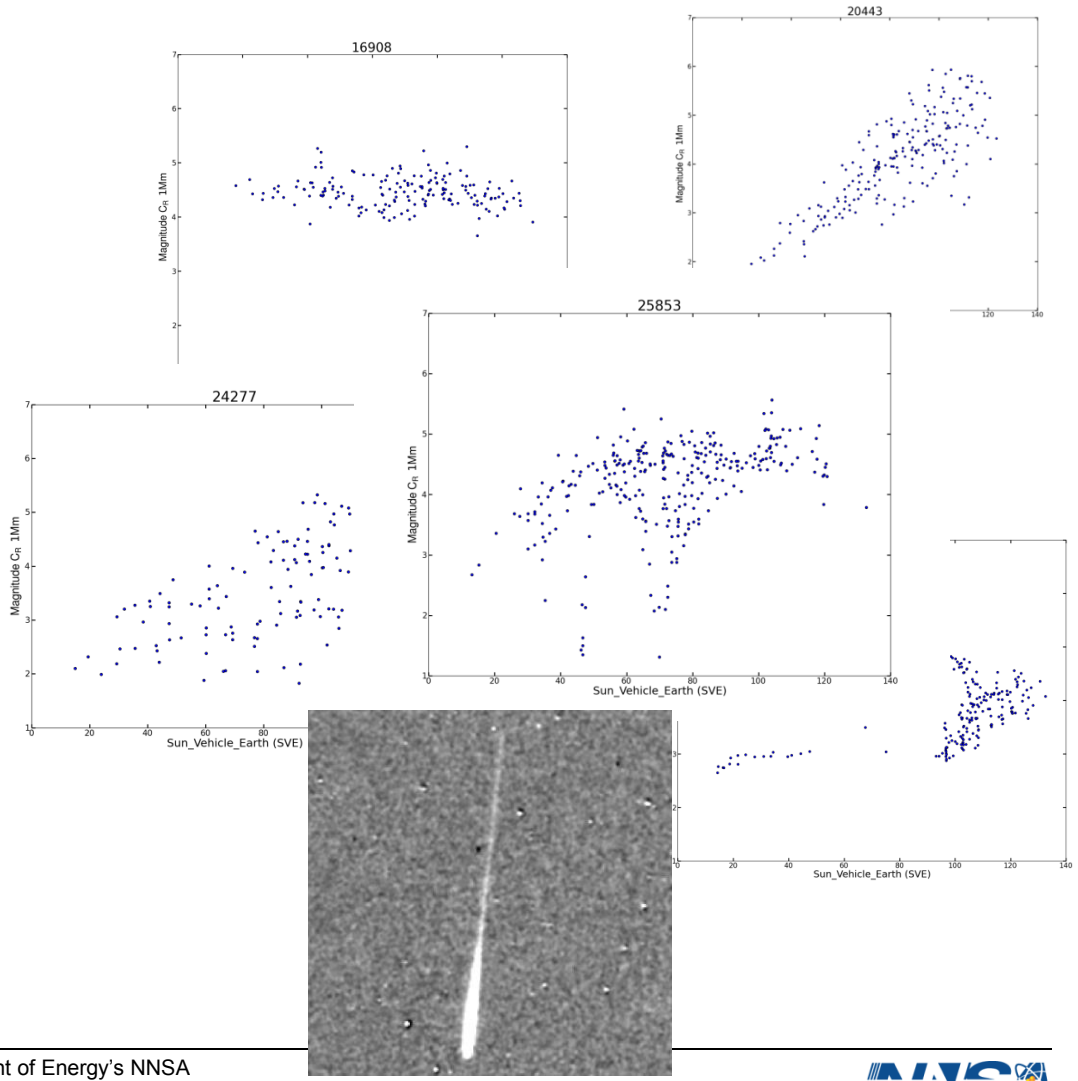
Bayesian Belief Network (BBN)

WAAS Tools – Evidence Facilitation, etc

# SSA Highlights

- **COLD & RQD2 Deployed to Haleakala**
- **COLD , South pointing “mini-Fence”**
  - **Designed, Fabricated, and Deployed in 6 months**
- **RQD2, Full sky persistent monitor**

- **Photometric Satellite “Fingerprinting”**
- **Glints as a discovery tool**

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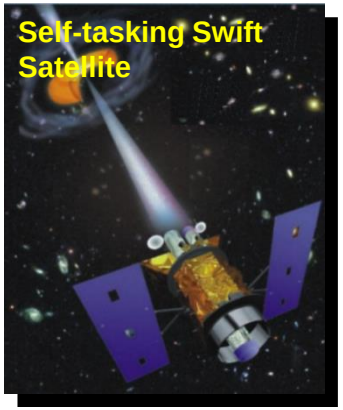
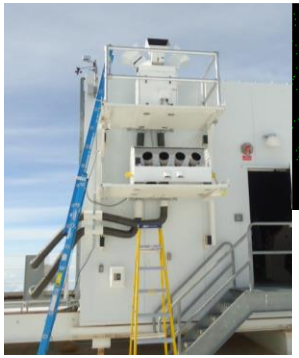
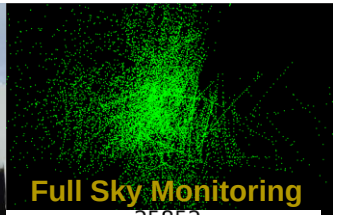
# Recent Program Highlights

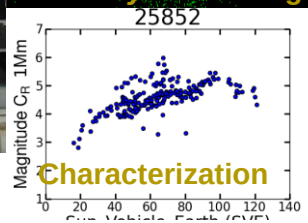
## From discovery to game-changing mission impacts



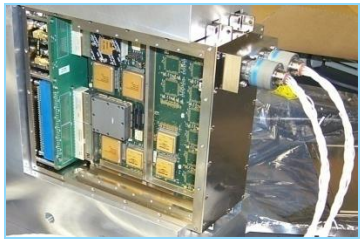

**Swift (2004)**
**Studying gamma ray bursts**



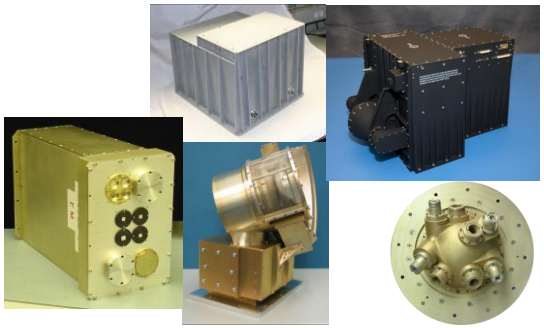


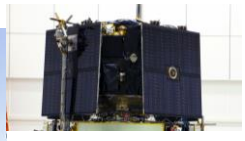

**Commercial Optics for LEO Debris (COLD) deployed 2012**

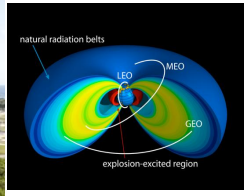


**MRM**
***2009 R&D 100 Winner***
**TeraOps Software Radio**

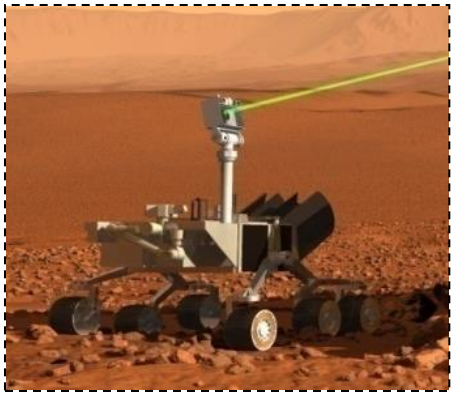


**SNDD Payloads (Ongoing)**






**HOPE – Space Environment Sensors (Launch Aug 2012)**



**ChemCam on Mars Science Lab (Landed Aug 2012)**



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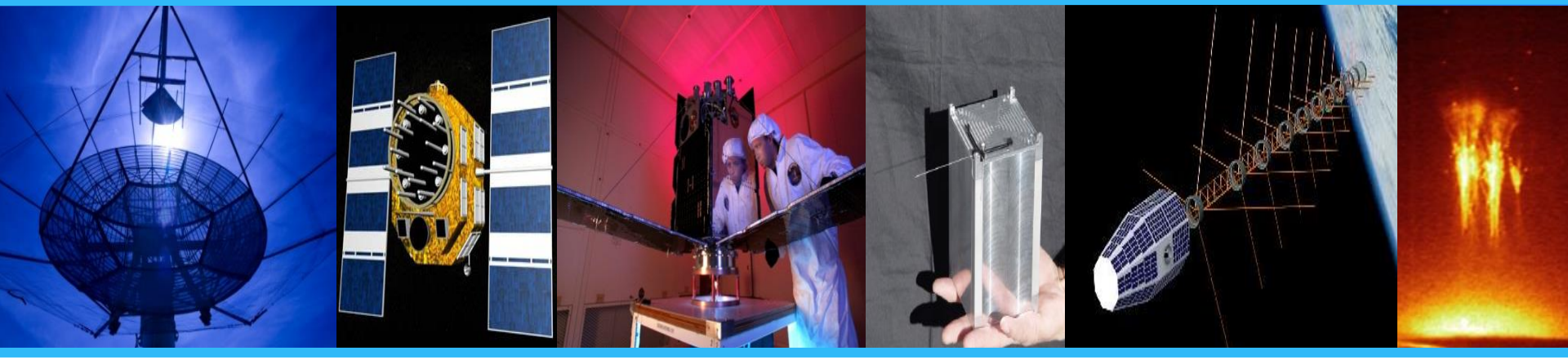
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA
NNSA
UNCLASSIFIED

# Responsive Space…



- **Exploit extant data streams to assist JSpOC in monitoring significant changes in defining the space environment**
- **Distinguish between natural and anthropogenic events**
- **Agile strategy for tracking and characterizing objects in space**
- **Rapid integration and reduction of data to facilitate and enable space operations**
- **Develop novel radar imaging methods for geosynchronous objects without benefit of preconditional information**

# ETRS: We pursue a mix of Bottom-up and Top-down program development

- Bottom up
  - Harness the passion of principal investigators
  - Respond to proposal calls and BAA's
  - Leverage LANL's basic R&D capabilities for DoD/IC partners
  - S&T base and innovation are key LANL differentiators

- Top down
  - Engage with high levels of government and other agencies
  - Participate in the development of technology roadmaps
  - LANL advantages:
    - Cost-effective
    - Rapid-development
    - Scientific and engineering breadth

# ETRS: Strategy for Top-down development

- Environment
  - Budget austerity affecting entire government
  - Interagency funding barriers

- Approach
  - Relationships key to program development in the interagency work
  - Credibility has been developed through quality on-time deliveries
  - Staff and management engaged with key military space agencies
    LANL has engagement with top industry performers

- Business models
  - “white hat” studies done directly for the government
  - Partnerships with key prime contractors
  - As appropriate, engage in competitive bids

# ETRS: Strategy for Bottom-up Development

- Environment
  - Portfolio flourishes based on the passion and world-class capabilities of the principal investigators involved
- Approach
  - Develop plans for synergistic investments with LDRD, etc.
  - Prioritize based on potential National Security applications
  - Nearly impossible to plan a strategy so focus on
    - Attracting & developing potential PI's
    - Support of PI's to contribute to the development of National Roadmaps
    - Allocation of resources to develop successful proposals
- Business models
  - External, competitive, peer-reviewed proposals submitted by nationally recognized scientific leaders

# ETRS: Method of Accomplishment

- Focus on National priorities:
  - Space Situational Awareness
  - RF Sensing
  - Spectral sensing
  - Image analysis, computer vision, patterns of life, info extraction
  - Space Weather (science competence but not big growth)
  - Space and Cyber

- Leverage broad relationships and investment dollars
  - Other government agency
  - CRADA's and Industry internal R&D investments
  - Evolve LANL basic research and NA-22 R&D investments into interagency activities that fund the transition to operations (cross the tech valley of death)

- Persistence in ongoing efforts

# Contacts

**General:**

- Overarching Issues & Strategy – Paula Knepper, pknepper@lanl.gov, (505) 665-1303

**By Sponsor:**

- Intelligence Community (IC) – Paula Knepper, pknepper@lanl.gov, (505) 665-1303
  - IARPA – Mark Dunham, mdunham@lanl.gov, (505) 667-0045
- Department of Defense – Paula Knepper, pknepper@lanl.gov, (505) 665-1303
  - Defense Threat Reduction Agency – Jon Schoonover, schoons@lanl.gov, (505) 665-0772
  - StratCom – Don O'Sullivan, dqosulli@lanl.gov, (505) 606-2289
  - ONR – Sheila Brandt, smbrandt@lanl.gov, (505) 667-5754
  - DARPA – Mark Dunham, mdunham@lanl.gov, (505) 667-0045
- DHS – Don O'Sullivan, dqosulli@lanl.gov, (505) 606-2289

**By Capability:**

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- Bio-threat & Defense – Chris Detter, cdetter@lanl.gov, (505) 667-1326
- Weapons Assessments & Forensics – Brian Bluhm, bkb@lanl.gov, (505) 667-2440
- Responsive Space – Eric Dors, edors@lanl.gov, (505) 667-9023
- Advanced Materials – Becky Olinger, bstreet@lanl.gov, (505) 664-0540
- Sensors, Signatures & Platforms – Jon Schoonover, schoons@lanl.gov, (505) 665-0772

# ETRS: Addressing national needs in the area of space and nuclear nonproliferation

## *2012 Nuclear Defense R&D Roadmap*

**Nuclear Material Detection:** Develop advanced passive and active detection systems for nuclear materials that exploit all data and signatures

**Technical Nuclear Forensics:** Develop technical methods that better reveal the provenance of rad/nuc materials that are interdicted or used illicitly, including prompt diagnostics

**Nonproliferation:** Improve capabilities to detect and characterize foreign special nuclear material production and weapons development activities

## *Limited Test-ban Treaty*
## *Comprehensive Test-ban Treaty*

**Nuclear Detonation Detection:** Develop/deploy capabilities for detecting and identifying nuclear explosions in the oceans, atmosphere, and space.

## *2010 National Space Policy*

All departments and agencies shall execute the following…

- **Develop and Retain Space Professionals**
- **Improve Space System Development and Procurement**
  - Reduce programmatic risk … **cost-effective opportunities to test high-risk components, payloads, and technologies in space or relevant environments**
  - **Embrace innovation** to cultivate and sustain an entrepreneurial U.S. R&D
- **Strengthen Interagency Partnerships**
- Departments and agencies shall make their capabilities and expertise available to each other to strengthen our ability to achieve national goals…

# ETRS: Overall Strategy is to execute basic R&D, mature technologies, and transition new capabilities to operations

Cradle to grave participation ensures application of cutting-edge technology to mission and provides clear understanding of operational need in return.

National Needs

Understanding

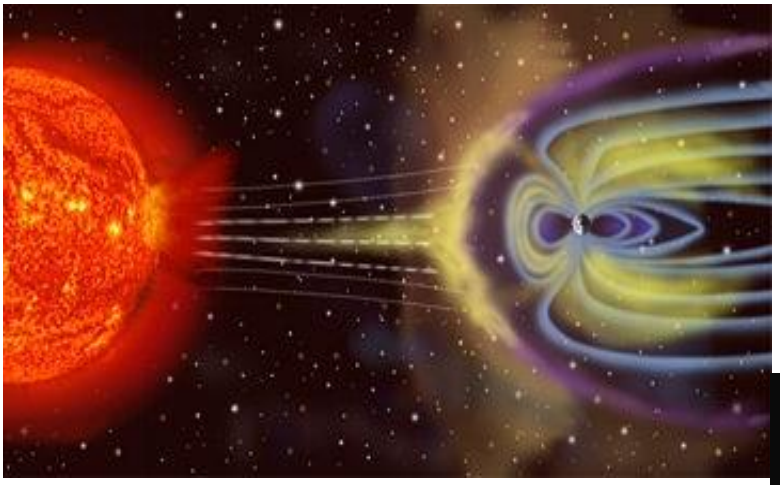
**Basic R&D**
(high-risk, high-payoff)
- NASA/NSF
- LDRD
- (DOE/SC, DOE/DP)

**Maturation**
(risk-reduction)
- NASA
- NA-22
- IWFO/WFO

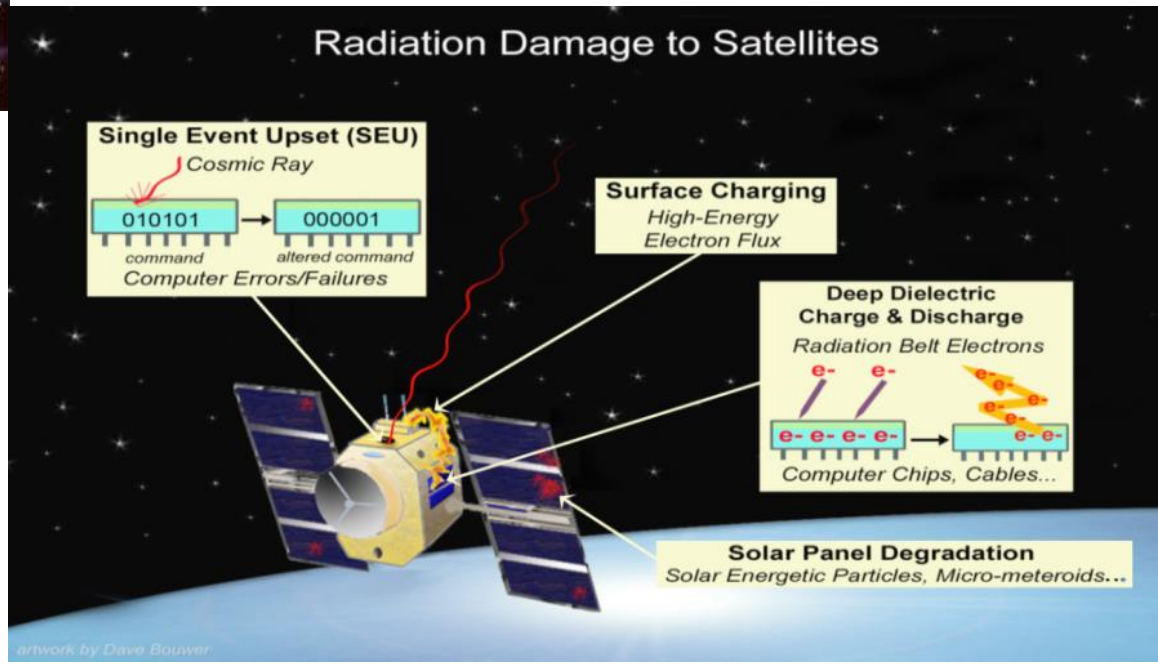
**Transition to Operations**
(revolutionary change)
- NA-222
- IWFO/WFO
- (NA-24, IAEA)

Technology and Infrastructure

# Space Weather has Significant Impacts



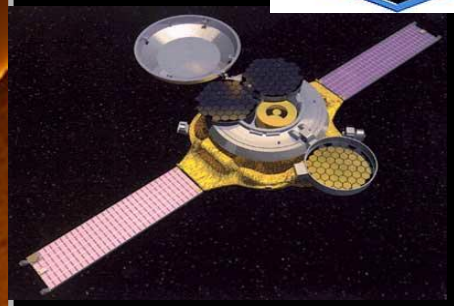
- **In Space**
  - **Satellite Operations**
  - **Astronauts**




- **On the Earth**
  - **Power Grid**
  - **Pipelines**
  - **Communications**

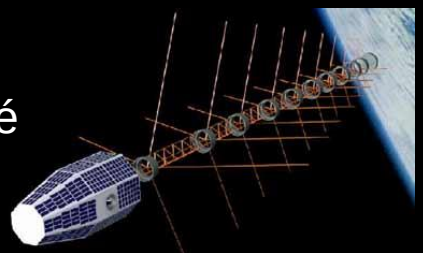
# LANL has Broad Space Weather Sensing Capabilities

## Heliospheric

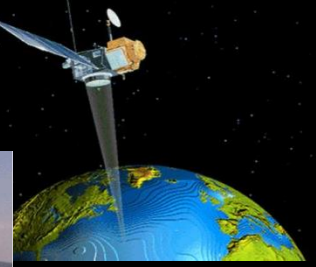


## Ionospheric

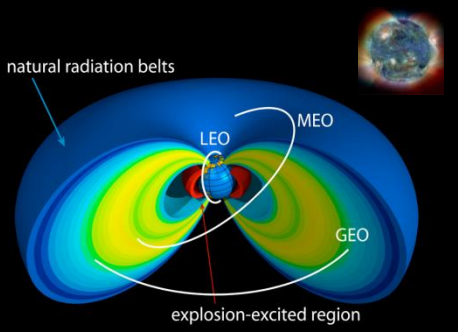
Forté



GPS TEC

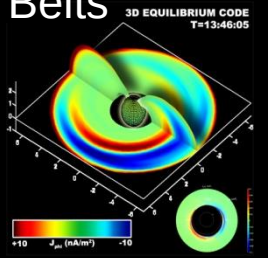


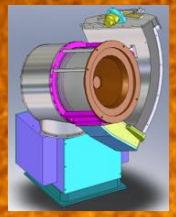
## Magnetospheric




Radiation Belts

Ring Current

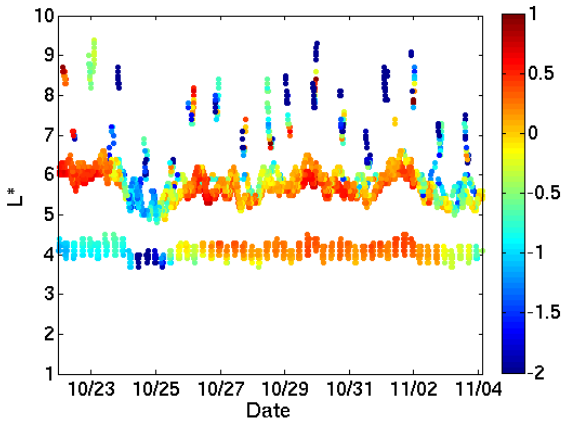


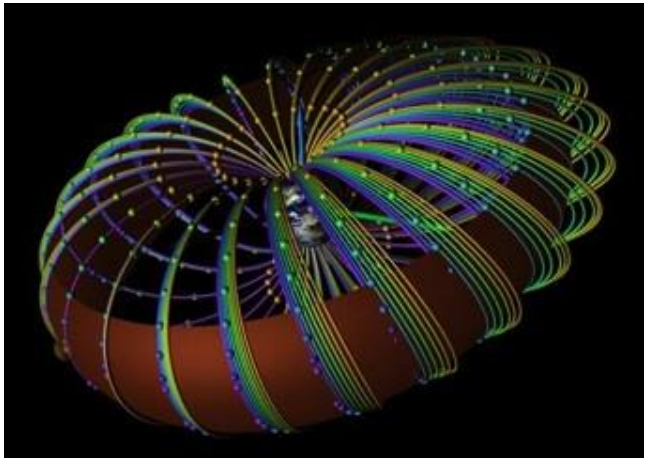
**Space Weather Instrumentation**

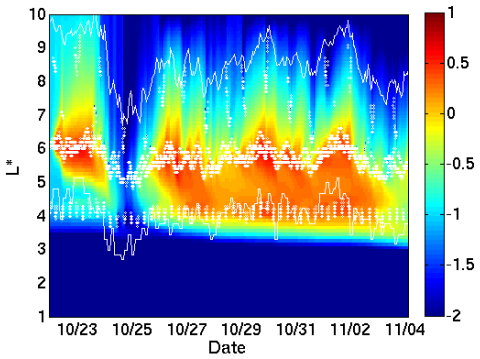
# Data Assimilation turns sparse observations into global, data-driven solutions

Sparse and/or Heterogeneous Observations



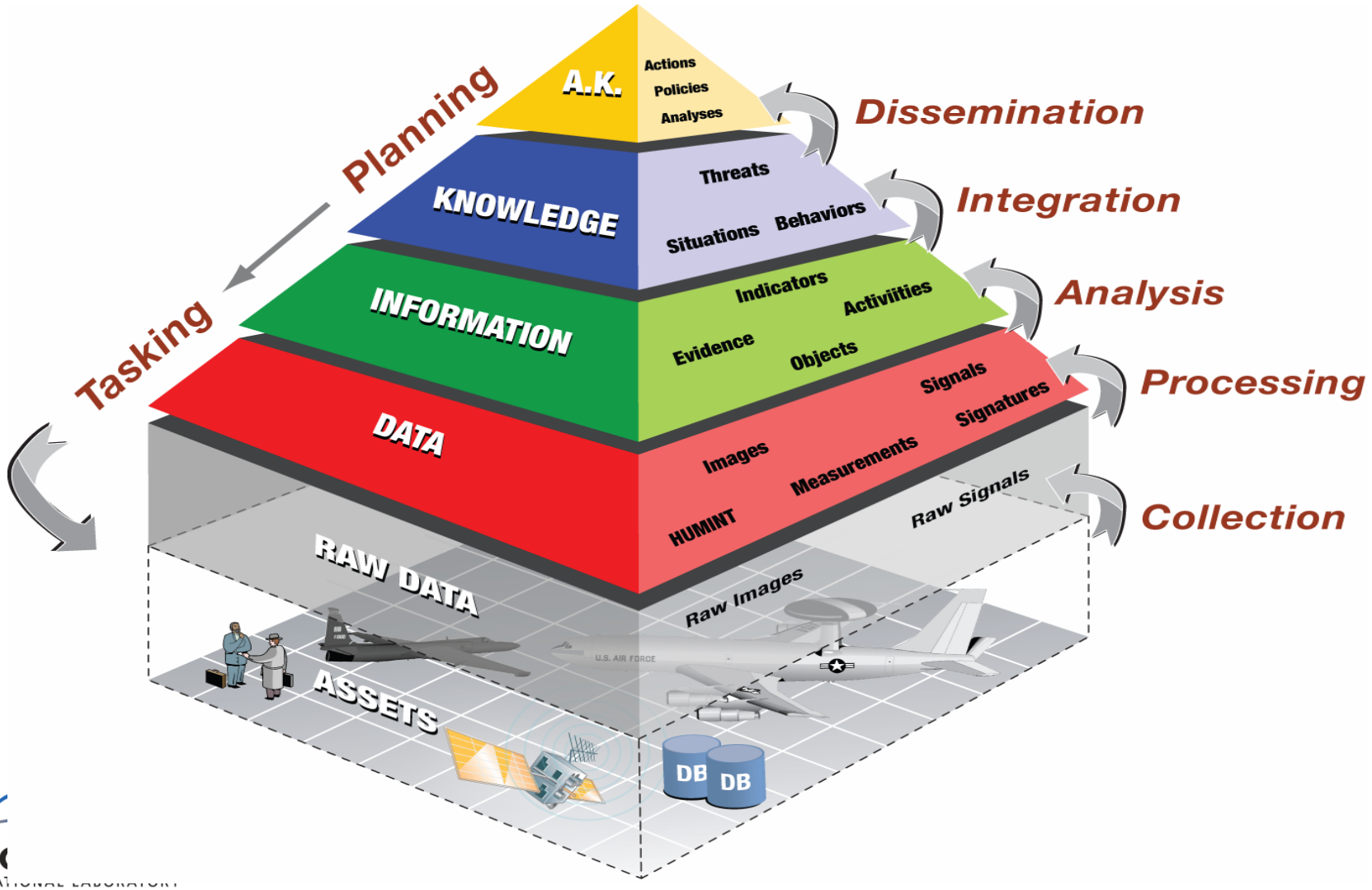

Complex Physical System





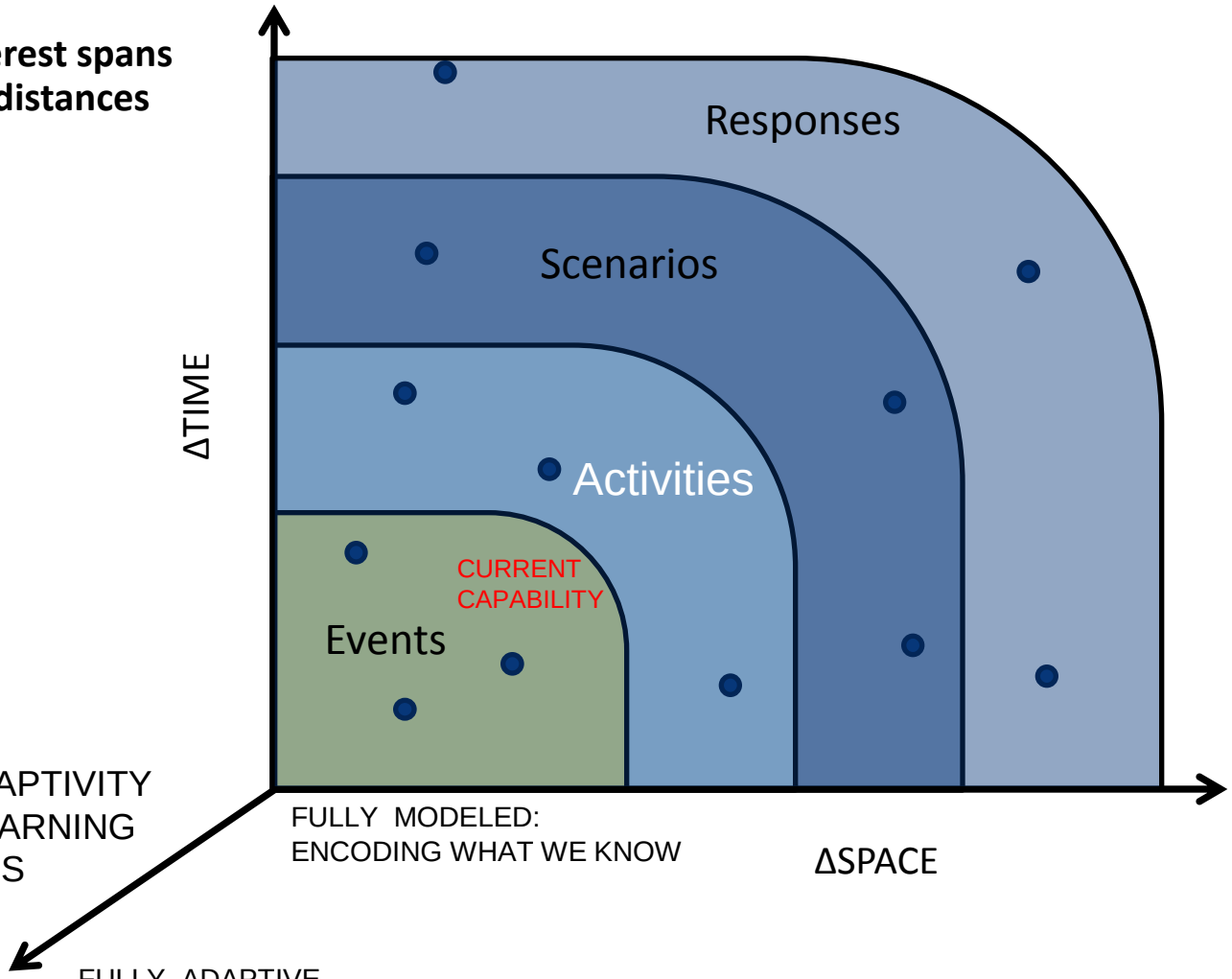

Global, Real-Time Data-Driven Solution

# Knowledge Discovery and Dissemination



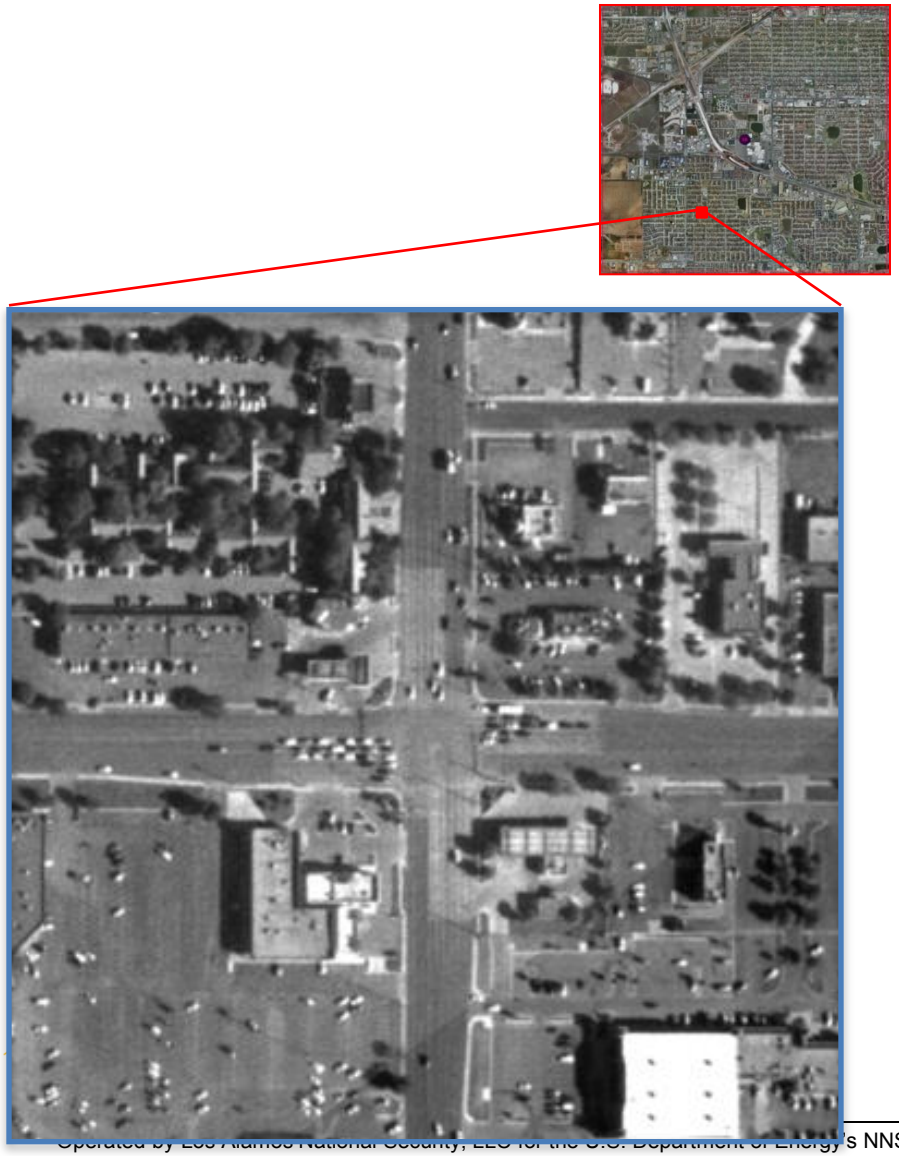
# LANL is developing integrated tools for event/activity/scenario detection and response

**Information of interest spans large space-time distances**

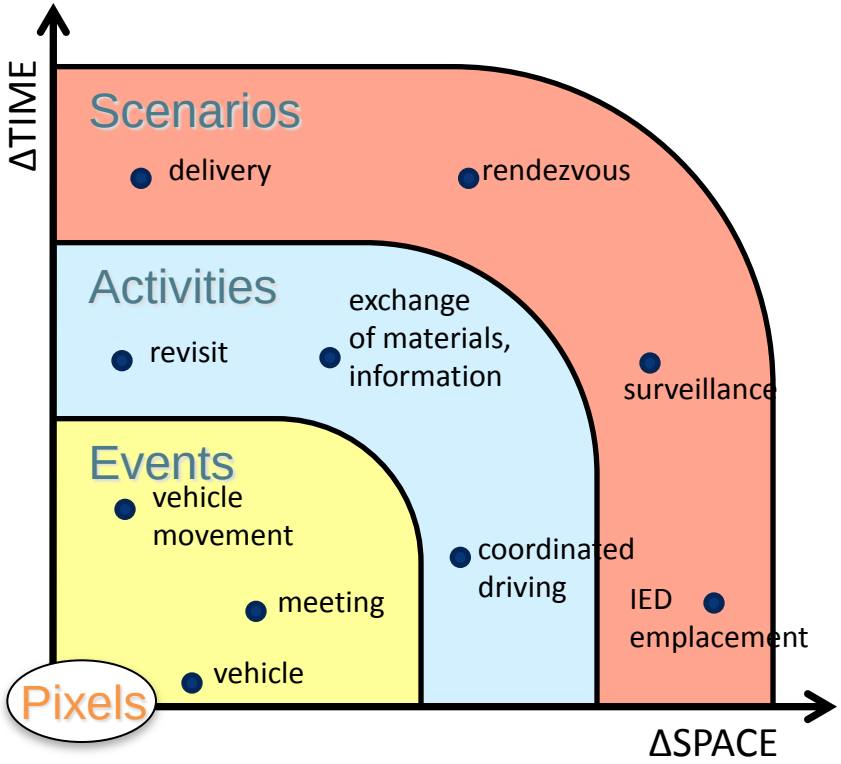


# Modeled Activity Detection

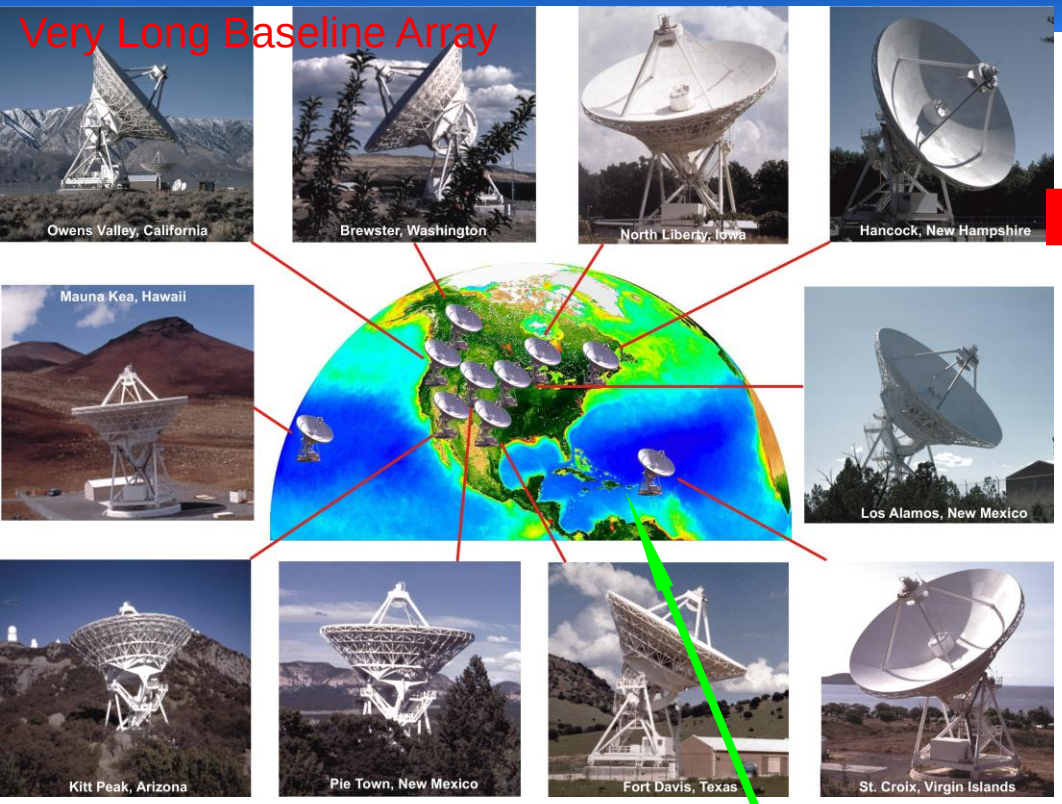
## First activity detection tools used by persistent surveillance analysts

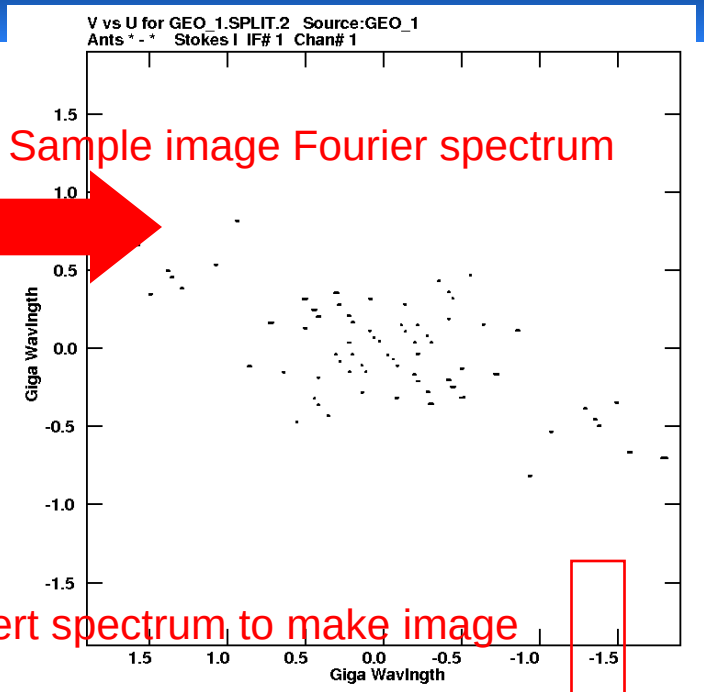


**Information of interest spans large space-time distances**

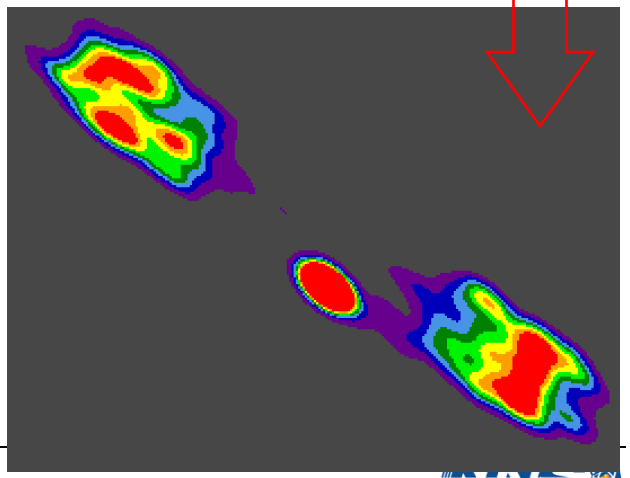


# Enabling technology: VLBA+Goldstone




Invert spectrum to make image

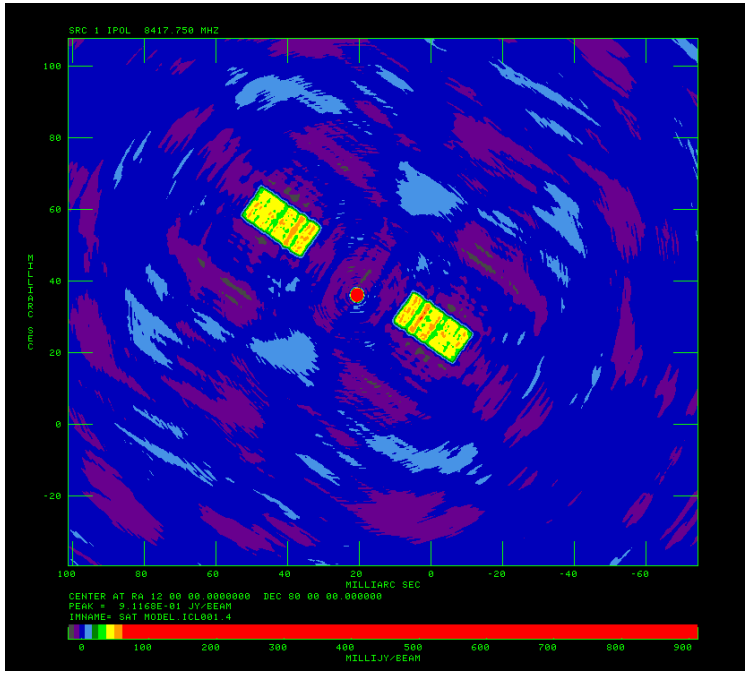


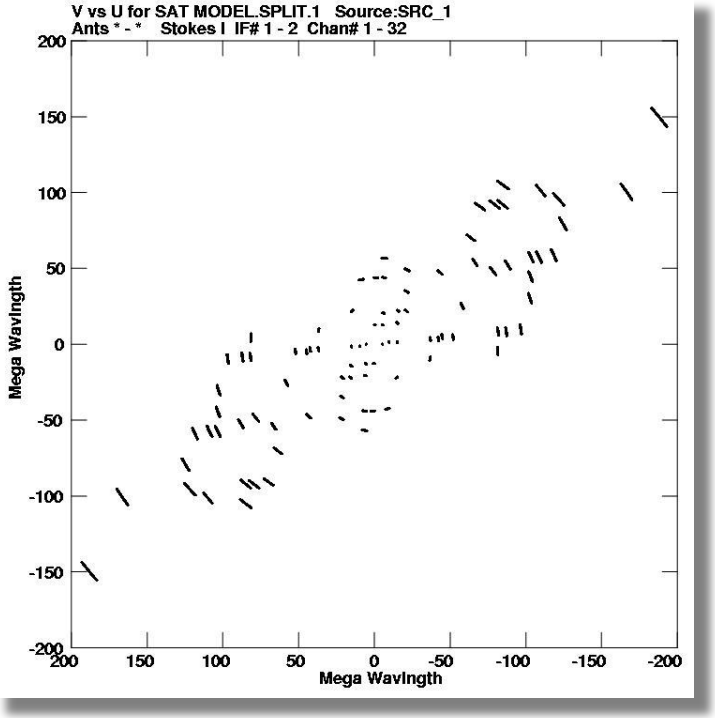
Illuminate with Goldstone radar Tx

# Proof-of-concept tests

- Use existing radio astronomy & radar assets
- NASA Goldstone/VLBA X-band steerable
- 3 experiments so far – 2 successful
- Illumination of geostationary TV broadcast satellites e.g. DirecTV-9S
- Fringes recovered but no detailed images yet
- Correlator geometric calculations are not sufficiently accurate currently
- Some novel image recovery methods have been developed – but not exercised on quality real data yet

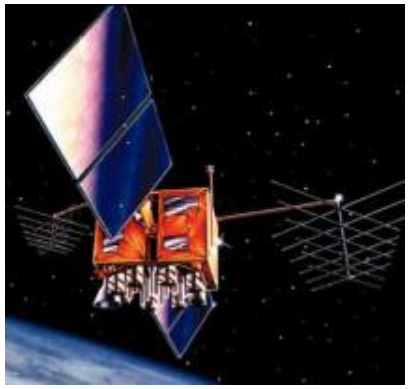
# Image reconstruction: synthetic data



# Solutions: Space-Based Nuclear Detonation Detection and Nuclear Fuel Cycle Remote Sensing

***These programs support DOE NA-22 in their missions to monitor nuclear weapons treaties and detect nuclear proliferation***

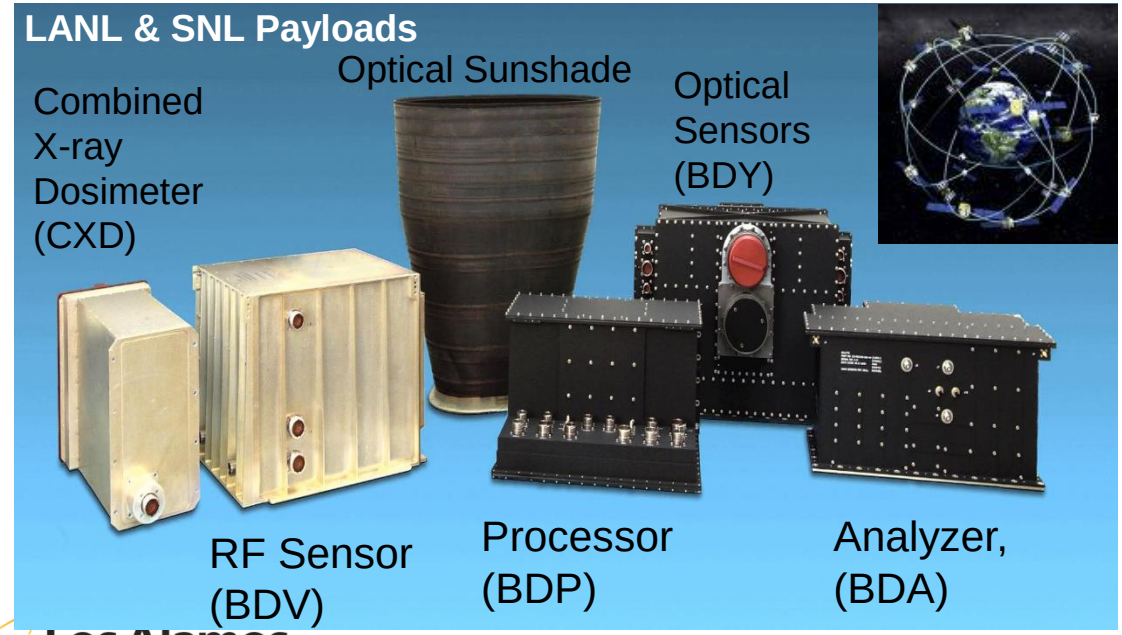


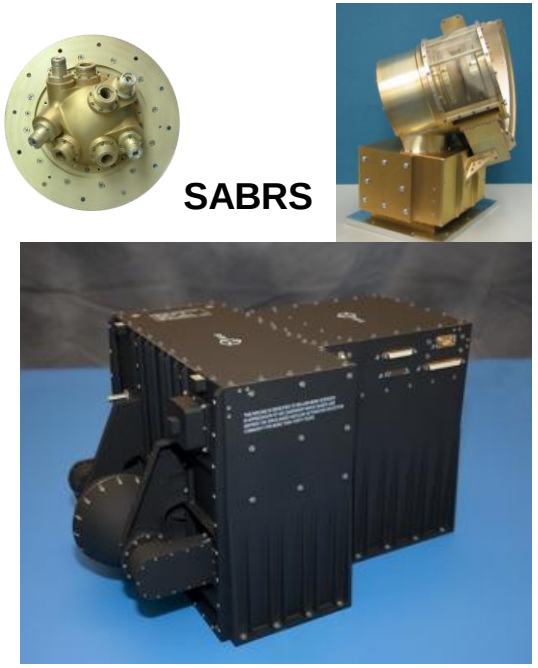
**SNDD provides sensors and on-orbit support for the U.S. Nuclear Detonation Detection System (USNDS) to meet interagency commitments. Joint program with SNL.**

**NFRS provides capabilities to detect and assess nuclear facilities and proliferation activities where access is either limited or denied.**

# New Technology: SNDD Highlights

- Delivered almost all of the GPS IIF payloads, first one launched May 2010
- Delivered the first Space and Atmospheric Burst Reporting System.
- Joint Architecture Standards for future systems (with SNL)
- Ongoing sponsor investments in R&D (SENSER, new instruments)
- Leveraging this work toward WFO sponsors



# But – The Emphasis Needs to Change

## From the SSA Conference and Elsewhere:

I don't need more pixels!

We've got data and information falling on the floor!

We can't get new systems certified!

We're supporting warfighters!

The cyber threat is real!

Get the human out of the loop!

We need to be predictive, not reactive!

We've got to make these systems work together!

"Space increasingly is congested, contested, and competitive…"

**How do we remain relevant to the most important problems?**